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IMPLEMENTING THE U.S. NAVY's HULL DEFINITION PROGRAM IN U.S. SHIPYARDS

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Dr. Gebhardt is a co-founder of CADCOM and its current Vice President; until August 1974 he served as Director of Technology in charge of all projects. Dr. Gebhardt taught naval architecture at the U.S. Naval Academy. At the University of Michigan he taught experimental ship hydromechanics and assisted in various ship design and test projects.

Dr. Gebhardt designed and directed the development of AUTOTANK, a computer-based system for automating the operation of ship model testing facility. The CADSHIP system is now used by the U.S. Coast Guard to review the structural integrity, damage and intact stability and seakeeping properties of new designs submitted to the Coast Guard for certification. Under his direction a NAVSEC-developed computer-aided arrangements program was implemented on a minicomputer system resulting in increased performance and the unique capability to automatically digitize three-view engineering drawings.

ABSTRACT

The unified Hull Definition System was designed by the U. S. Navy so that the digital computer could be used to assist in the "fairing" process. CADCOM, Inc. was tasked by MARAD and the Navy with transferring this technology to the U. S. shipbuilding industry. This transfer involves four steps: (1) enhancing the program to make it meet the needs of the industry, (2) generating four standard versions of the program, (3) creating documentation, and (4) conducting training seminars for potential users. The program does not replace the conventional methods of designing hull forms; rather, it functions as an interactive tool which allows the designer to retain control over the surface he is defining. He still performs his traditional procedures, but he performs them more quickly and accurately than before.

I. OVERVIEW

The job of defining a ship's hull form with sufficient accuracy, precision, and completeness to enable a shipyard to build the ship which the designer had in mind when he developed his lines plan is difficult. Traditionally, the design agent draws a lines plan to a relatively small scale and then gives it to the shipyard as part of the contract plans and specifications package. Upon receipt of the contract, one of the first tasks the shipyard must undertake is to generate a fair, accurate definition of the hull form which faithfully represents the contract lines plan. Before systems such as AUT0KON, SPADES, and STEERBEAR came into widespread use in large shipyards, this task was accomplished by hand on the mold loft floor - as it is today in many small shipyards - by highly skilled shipyard personnel at a large expenditure of time and money.

At first glance, the fairing process seemed to be well suited for computers, and, indeed, since the early 1960s, fairing programs of various types have been used, with varying degrees of success, by U. S. shipyards. Unfortunately, all of the programs currently in use seem to have drawbacks, and none, to our knowledge, has been universally acclaimed as being able to solve all fairing problems.

The basic problem, as we see it, is that there is no unique solution to the typical fairing problem. Put as concisely as possible, the problem reduces to finding a surface which

(a) passes through some finite number of points

(b) meets some finite number of global constraints, such as volume, centroid, etc., and

(c) is judged "fair" by an experienced Naval architect.

Obviously, an infinite number of surfaces can meet requirements (a) and (b); and some of these will presumably meet requirement(c).

The fact that more than one acceptable solution exists to the problem has led us to the fundamental conclusion that for the digital computer to be useful in the process of full-scale hull form definition, its role must be confined to simulating and enhancing the drawing board/mold loft environment. Such a role will allow the designer/loftsman to perform the tasks and procedures he traditionally performs; but with the use of a computer, he will be able to perform them much faster and more accurately than ever before.

Specifically, the ideal hull definition system should have the following basic characteristics:

(a) It should create a surface definition from a series of intersecting line segments which lie in the surface.

(b) It should be able to produce information about any line which will allow the operator to easily judge whether the line is "fair".

(c) It should enable the operator to move point(s) on any line so as to achieve acceptably fair lines.

(d) It should be able to output, as a minimum, a complete table of offsets, nes drawing, and the offsets of the intersection of any plane and the defined hull surface.

(e) It should produce lines that are defined by the mathematical equivalent of the flexible spline normally used by Naval architects and loftsmen.

At the 1975 REAPS Technical Symposium Mr. M. E. Aughey of the Naval Ship Engineering Center, Hyattsville, Maryland, described a program which essentially meets all of the above requirements. In response to requests by the REAPS participants, MARAD initiated a joint MARAD/Navy effort to transfer this technology-to the U. S. shipbuilding industry. CADCOM, Inc. was subsequently chosen to effect the transfer by performing the following tasks:

(a) Enhancing the program somewhat to make it responsive to the needs of the U. S. commercial shipbuilding industry

(b) Generating four standard versions of the program

(c) Creating full and complete program documentation for the entire spectrum of potential users, and

(d) Conducting training seminars to speed the technology transfer process.

Subsequent chapters of this paper briefly describe the program, its impact on current methods and systems, our implementation plan, and future possibilities for the use of the program.

II. HULL DEFINITION CAPABILITIES

The Unified Hull Definition System is designed to meet the fairing needs of the U.S. shipbuilding industry for the foreseeable future. The program is extremely flexible and capable of producing accurate and fair definitions of a wide variety of hull forms. The procedure for using the program parallels the conventional methods of designing a limes plan and provides the user with an interactive tool that allows him to control the surface definition until he judges it to be "fair". The program is written in a subset of ANS FORTRAN IV and consists of some 45 modules and approximately 5000 source statements.

In order for the program to be better suited to perform in a production-type design environment, we have added certain enhancements. These include additional engineering capabilities and modifications that will allow a more efficient user/program interface. The program capabilities, as now implemented, include:

(1) Production of the traditional three-view lines plan of faired stations (or frames), waterplanes, and buttocks

(2) Printed output of a full-scale table of offsets, including first and second differences

(3) production of isometric views of selected lines

(4) Output of standard hull form hydrostatic characteristics (volumes, areas, centers, etc.), and

(5) Output compatible with AUTOKON E-File

Most computerized lines fairing methods lack continuity and form definition in the longitudinal direction. Stations or frames are defined, but interpolation techniques are required to determine the shape of the hull between frames. Experience has shown that no interpolation technique is universally suitable.

The hull definition program overcomes this difficulty by defining the hull and other surfaces with longitudinal lines as shown in Figure II-1. The shape of any frame or station is then uniquely defined by the connected sequence of the points of intersection of the longitudinal lines at the transverse plane of the frame or station. The tool used for connecting the points is the mathematical batten in the form of a parametric spline with slope and curvature continuity. The mathematical lines defined by this parametric spline are computed and used in the endpoint-tangent or segment form. Each segment of a line (between points) is described by X, Y and Z coordinates and tangent vectors at each end.

To utilize the program, the designer must define his hull form through the use of control and other lines in the procedure shown in Figure II-2. These lines are the boundaries between hull sections with continuity in slope and curvature. They will include, on a standard form, the center line profile, deck-at-edge, flat of side and bottom areas, half-siding and any knuckles or chines. These lines will be fixed early in the hull definition process and will act as the reference lines between which all fairing is done.

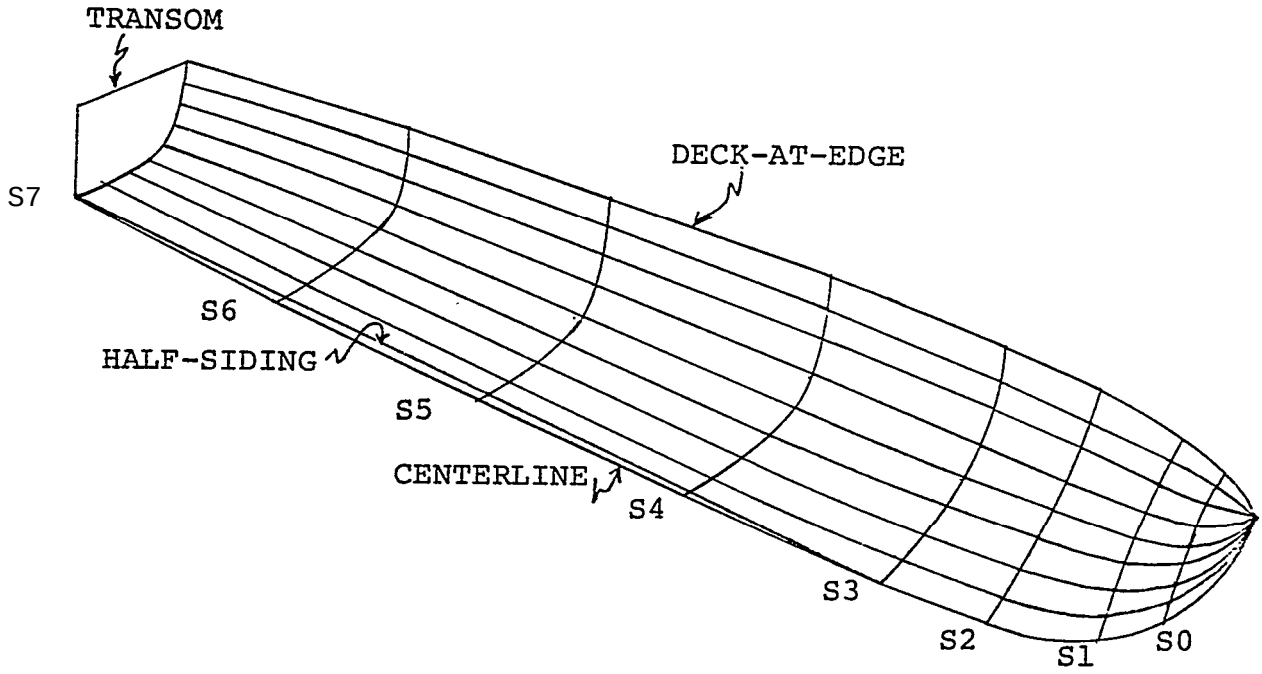

Figure II-1
Port Half-Shell View

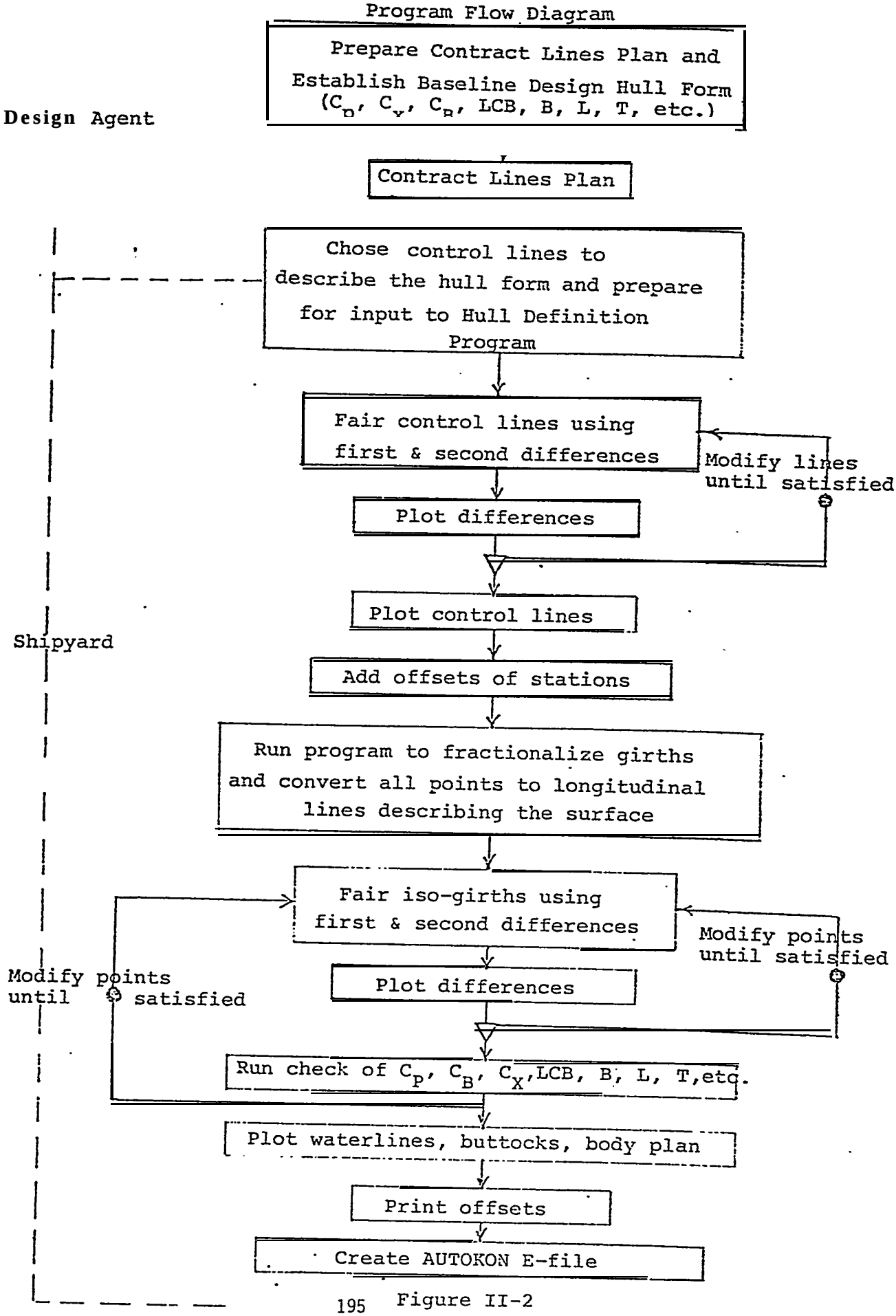
Program Flow Diagram
Design Agent
Prepare Contract Lines Plan and Establish Baseline Design Hull Form (C_p, C_x, C_B, LCB, B, L, T, etc.)
Contract Lines Plan
Chose control lines to describe the hull form and prepare for input to Hull Definition Program
Fair control lines using first & second differences
Modify lines until satisfied
Plot differences
Plot control lines
Shipyard
Add offsets of stations
Run program to fractionalize girths and convert all points to longitudinal lines describing the surface
Fair iso-girths using first & second differences
Modify points until satisfied
Plot differences
Modify points until satisfied
Run check of C_p, C_B, C_X, LCB, B, L, T, etc.
Plot waterlines, buttocks, body plan
Print offsets
Create AUTOKON E-file

 Figure II-2

Once the designer has faired the control lines, he enters a "rough" set of stations to provide a general definition of the hull surface. By dividing each station or "girth" into equal "girth fractions", he can, through the program, pass a parametric spline from bow to stern through points of equal percentage. These is o-girth lines are the lines he will fair. Enough is o-girth lines must be used to sufficiently define all regions on the surface, but no more than necessary should be used.

The designer can, as a program option, fair a portion of or a complete iso-girth, station, frame or control line. By observing the plot of the second differences of any line, he can manipulate the points for re-input into the program to produce a line that suits his notion of "fair". Throughout the fairing process he may request a print of the standard ship hydrostatic characteristics to ensure that his manipulation of the hull surface remains within the design parameters.

As you can see, the designer retains control over the surface he is defining. He can stop the fairing process at any point to check his design parameters, and through the use of available output options, he can satisfy many of the hull design report requirements in the construction process.

III. THE IMPACT ON CURRENT OPERATIONS

III-1 Hardware Requirements

The Unified Hull Definition Program is written as a stand-alone package which can be implemented on a wide variety of modern computer systems. Memory requirements vary depending on the target machine. However, the program has been successfully implemented on a minicomputer with 64K bytes of memory. The important factors which will determine the success or failure of the implementation at any particular facility are:

(a) The availability of a drafting machine and/or CALCOMP-compatible plotter

(b) The average turn-around time at the facility, and

(c) The availability of an on-line graphics terminal, such as a Tektronix 4010, to preview hard copy output.

It must be emphasized that the hull definition software is very interactive in nature and can be utilized most effectively when the operator can get fast response from the computer both in terms of printed output and plotted results. Hence, the snorter the time required to obtain a plot, the easier it is to use the program.

CADCOM is currently modifying the graphic output to make it compatible with all plotters and drafting tables which can handle input data in the ESSI format. In addition, CALCOMP-compatible plotters will be supported by the software, and either EIA or ASCII codes may be specified as program options.

In order to take full advantage of the ESSI plotters to plot circular arc segments as well as straight lines, we have developed an algorithm which will replace all parametric spline segments with a combination of straight lines and circular arcs within a specified tolerance.

III-2 An Interface to the AUTOKON System

To further enhance the utility of the Unified Hull Definition software in shipyards which are now using or are planning to use the AUTOKON 71 system, we have designed a program option which will be supplied with each standard version of the program. This option will build a replica of the so-called E-File, which is normally generated by the AUTOKON FAIR-2 module. This data can be subsequently used by the two AUTOKON modules **DRAW** and **TRABO, as shown in Figure III-1. DRAW produces an ESSI element paper or magnetic tape for plotting standard AUTOKON outputs on a drafting machine. TRABO TRANsfers the BOdyplan data in the E-File into the permanent AUTOKON database.**

The data required by AUTOKON from the fairing module (either the Hull Definition Program or FAIR-2) consists of, at most, the following:

(a) The main dimensions of the ship, that is, I.D. rise of floor, bilge radius, max height, max half-beam, etc.

(b) Transverse frame definitions

(c) Waterline definitions, and

(d) Buttock definitions.

The Hull Definition Program will generate an E-File containing the above data which, to the other AUTOKON modules, should be literally indistinguishable from an E-File generated by the standard AUTOKON fairing module.

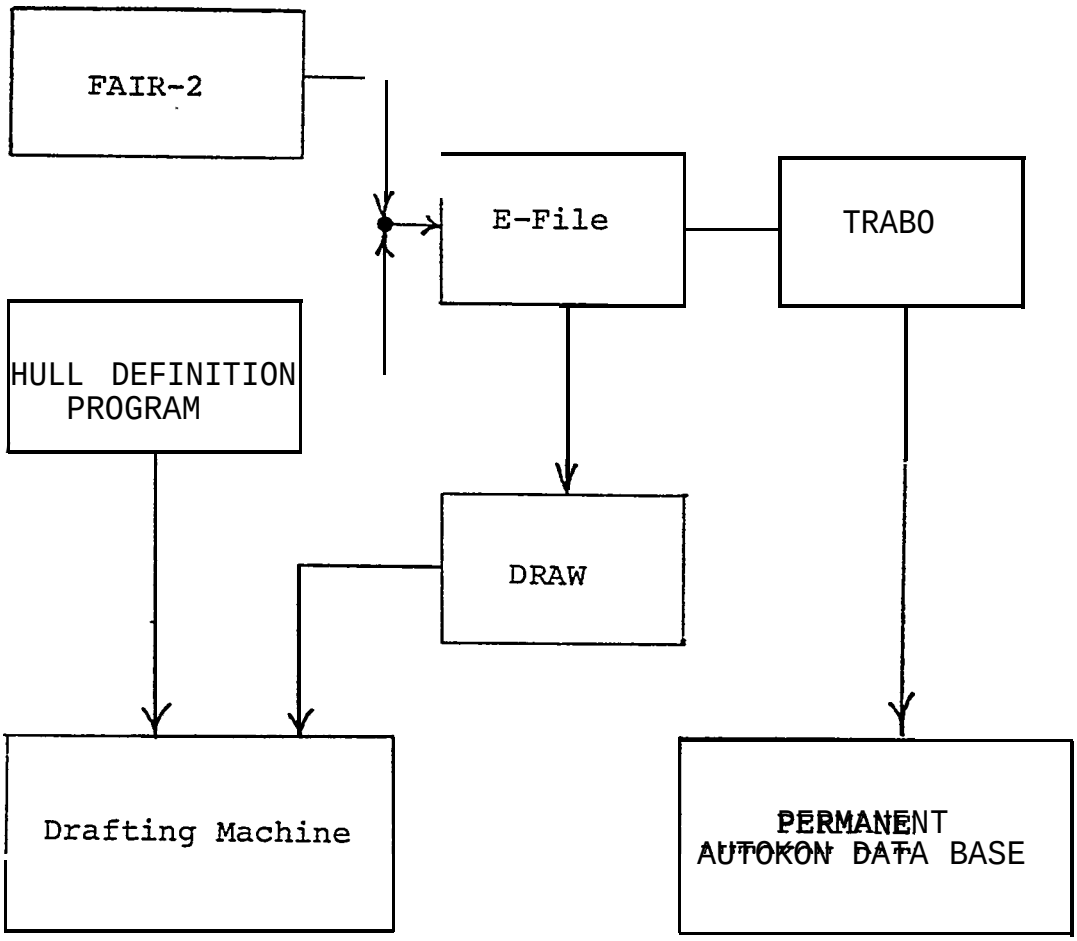

Figure III-1

The Hull Definition Program/AUTOKON Interface

IV. IMPLEMENTATION PLAN

The successful transfer of the Navy-developed hull definition program to the shipbuilding industry will depend heavily upon the training in program usage and maintenance received by the shipyards. We envision that three types of individuals will be directly involved with the program at the shipyards; therefore, we are designing the documentation and training information to reflect the specific needs of each type.

Designer's, user's and programmer's manuals are being written to cover each of these expected areas of involvement. These manuals will not only explain the basic concepts of hull definition and the imformation needed to perform the design functions, but will also provide the user with the details required to interact with other individuals involved in the hull definition process.

In order to assure a smooth implementation, CADCOM will conduct a workshop later this year so that potential users may become familiar with the program. The workshop will consist of two separate meetings held approximately one month apart, with the first one now scheduled for late October. This first session will consist of a lecture-discussion - which will include a Presentation of basic concepts, user options, and input and output procedures - followed by a question-and-answer period and demonstrations of the program applied to typical fairing applications. If possible, hands-on experience will be provided.

Each participant will be provided with a training manual which will include sample problems and visual aids. In addition, each participant will be provided a source deck of the program and complete documentation and installation instructions.

The follow-up workshop session will be held for the purpose of answering questions and providing guidance in the use of the program after participants have had an opportunity to install and utilize the program at their own facilities.

V. POSSIBLE FUTURE DEVELOPMENTS

The programs which will result from this project should meet the majority of the requirements of U.S. shipyards for the foreseeable future. At the same time, the appearance on the scene of such a flexible, versatile, unified tool for surface definition opens the door to many possibilities for enhancing and optimizing other aspects of ship design and construction. One development which we believe will have a significant impact on the way ships are designed and built should occur gradually as design agents find that they can design new hull forms from scratch using this program more quickly and easily than they can manually. If the shipyard that then-builds the ship also used the Hull Definition Program to fair the contract lines, the design agent can transmit the lines plan to the shipyard as a deck of cards which can be checked for any "shaggy" spots that the designer did not catch. These spots can be tidied up very economically.

At the present time several enhancements are in various stages of development. If added to the program, they could enhance its capability by providing the following:

(a) a developable surface module generating a ruled surface between any two control lines

(b) a curved plate development module for generating an expansion of any portion of the hull surface

(c) an interface module for creating data bases for other shipbuilding systems, notably SPADES and STEERBEAR

(d) An implementation of the program on a minicomputer-driven interactive graphics CRT Terminal, with 3-D curve visualization capability and on-line, interactive modification of offsets in response to first and second difference displays, and

(e) Canned fairing algorithms for automatically “fairing” lines or families of lines that are almost fair.

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